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ATTENUATION MEASUREMENTS OF EAR MUFFS AT STRATHCONA MINE 1984

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ELLIOT LAKE LABORATORY

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by

M.U. Savich* and J.K. Weglo**

ABSTRACT

Ear muffs are the main protection of the mining workforce for the attenuation of noise. The measurement of head size as against clamping force as well as the condition of the ear muffs are demonstrated as important variables in this attenuation of noise. The "NO NOISE" ear muff attenuation was about 13 dBA average with a standard deviation of 6 dBA at the Strathcona Mine. The Mark V ear muffs, replacing those in this study, based on clamping force measurements versus head size can be expected to produce attenuation >14 dBA.

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MESURE DE L'EFFICACITÉ DES CASQUES ANTIBRUIT À ATTÉNUER LE BRUIT À LA MINE STRATHCONA 1984

par

M.U. Savich* et J.K. Weglo**

RÉSUMÉ

Les casques antibruit sont la principale source de protection contre le bruit pour les travailleurs miniers. La mesure de la taille de la tête par rapport à la force de serrage ainsi que l'état des casques antibruit sont indiqués comme étant d'importantes variables de l'atténuation du bruit. Lors de l'étude à la mine Strathcona, le niveau d'atténuation du bruit "NO NOISE" des casques antibruit était en moyenne d'environ 13 dBA avec un écart type de 6 dBA. Cependant, d'après les mesures de la force de serrage par rapport à celles de la taille de la tête, les casques antibruit Mark V qui ont remplacé les casques utilisés dans cette étude pourraient assurer une atténuation du bruit de >14 dBA.

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INTRODUCTION

As part of the ongoing program of abating noise pollution at Falconbridge Mines measurements were taken to test the efficiency of ear muffs which were being used.

Tests were carried out at the Strathcona Mine where the following ear muffs were tested:

1) "NO NOISE", model NN3-F, the Hellberg Standard Volume Hearing Protector, hard hat attachment;
2) Mark IV, MSA, worn behind the head;
3) Peltor H7P3e, hard hat attachment;
4) Bilsom Viking Muff 2314, hard hat attachment; and
5) David Clark, Model E-705, Straightaway.

Most of the analyses were carried out on "NO NOISE" ear muffs, model NN3-F, because they were the ones used by 95% of the workers. The framework and method, as well as theoretical and practical considerations, are outlined in the main report, which should be read to compare Strathcona Mine results with other Falconbridge mines.

The latter three types have recently come into use in the mine. Only one test, for head size and clamping force, was performed on the David Clark muffs. On the other muffs both tests were performed, for head size/clamping force and attenuation, but the Peltor H7P3e and Bilsom 2314 muffs had very small populations (2 tests on the Peltor and only 1 test on the Bilsom muff).

Attenuation characteristics of the ear muffs, as supplied by the manufacturer using the ANSI protocol (reference) are given in Table 1. Noise reduction ratings (NRR) given in Table 1 are those which were supplied by the manufacturers. From these rating values it appears that all muffs provide relatively equal attenuation.

Table 1 - Attenuation characteristics of ear muffs acquired for testing (ANSI S3.19-1974).

No.	Ear Muff	Characteristic	Frequency Hz									NRR
			125	250	500	1000	2000	3150	4000	6300	8000	
1	"NO NOISE" Model NN3-F Hellberg	Mean	16.2	19.9	25.2	34.1	36.0	39.2	39.0	40.3	38.1	24
		Std. Dev.	2.5	1.8	2.0	1.7	2.2	3.1	2.0	4.0	4.1	
2	Mark IV, MSA	Mean	17.0	18.0	29.0	36.0	38.0	44.0	44.0	43.0	93.0	24
		Std. Dev.	2.6	2.6	3.1	3.2	4.1	7.2	4.6	4.7	5.7	
3	Peltor 47P3e	Mean	14.1	18.8	28.1	36.2	35.6	38.4	35.0	35.5	35.4	24
		Std. Dev.	2.1	2.0	3.0	2.1	2.2	2.3	2.1	2.1	2.4	
4	Viking Muff No. 2314, Bilsom	Mean	15.0	21.0	27.0	37.0	36.0	38.0	42.0	42.0	39.0	25
		Std. Dev.	1.8	2.0	2.5	2.8	1.5	2.3	3.0	3.7	3.6	
5	David Clark Model E-705 Straightaway	Mean	12.0	17.0	30.0	35.0	35.0	36.0	37.0	32.0	30.0	--
		Std. Dev.	2.5	3.0	4.6	5.6	4.5	4.3	4.2	4.1	2.9	

MEASUREMENTS AND RESULTS

At the Strathcona Mine the db 307 Metrosonics instrument was employed in virtually every test, and with its greater range it provided more exact attenuation measurements than other instruments.

The inability of the Brüel and Kjaer (B and K) dosimeters to provide exact attenuation figures when measured levels are greater than 115 dBA, or less than 80 dBA, may have been responsible for resultant attenuation differences.

The first technique at the Strathcona Mine employed one B & K dosimeter (microphone under muff), and one db 307 Metrosonics (microphone outside the muff). Both instruments were either OSHA (doubling at 5 dB), or ISO (doubling at 3 dB), monitoring noise levels simultaneously. This technique allowed the second technician to simultaneously monitor, with his hand-held instrument, his partner's dosimetry. This technique required a lot of 'man-handling'. Microphones and equipment had to be switched around at least four times per test; a complete scooptram test required 12 trips and many interruptions. To decrease inconvenience to the worker and to lessen the time required for dosimetry, two more pockets were added to the vest. Tests then took less time to complete because we to changed the microphones from side to side only once. The B & K was used for inside muff readings, and the Metrosonics for exterior readings.

Sound level tests with the hand-held instruments took longer to complete. Head size was measured with outside calipers, and clamping force with a manual balance.

HEAD SIZE AND CLAMPING FORCE

Head size and clamping force tests were performed on four ear muffs,

with varying populations (see Appendix A and summary results in Table 2).

In Table 2 it can be seen that results of 16 measurements on muffs No. 2, 3 and 4 are very similar to the results of 93 measurements on No. 1 "NO NOISE" ear muffs.

Ear muffs deteriorate rapidly with use. Mark IV MSA muffs have a strong clamping force, 1277 (gwt), but a very high standard deviation as well, 417 (gwt). Ninety per cent confidence in results is 1277 $\pm$ 234 (gwt), which is almost the same as factory-tested brand new muffs.

The normal frequency curve of population - 60 has two maxima (Figure 1). The first maximum is related to the curve's positive skewness. The flatter curve was plotted from clamping force tests on population - 93. Here too, we have head sizes of small bizygomatic diameter, 12.0 cm to 13.0 cm.

If we look at these two curves we see that their essences differ, and that a large number of measurements are needed for proper evaluation. The shape of the flatter curve is considered to be platykurtic. We measure peakiness by using the following formula:

$$\text{peakiness} = \frac{m_4}{s^4}$$

Moments are based on the sum of deviations from the mean of each of the individual sample details in a distribution. Our formula for peakiness is based on the fourth moment divided by the standard deviation to the fourth power.

$$m_4, \text{ fourth moment} = \frac{\Sigma(X - \bar{X})^4}{n} = \frac{\Sigma x^4}{n}$$

$$= 1.2 \text{ (platykurtic)}$$

The numerical value of this equation will be equal to 3 for a normal curve. For a leptokuric curve our answer will be greater than 3, while for a platykurtic curve it will be less than 3. What we can conclude is that, in practice, we must work with large numbers of measurements to obtain valid

Table 2 - Summary results of head size and clamping force tests

No.	Ear Muff	N*	Head Size (cm)		Clamping Force (gwt)		Comment
			Mean	Std. Dev.	Mean	Std. Dev.	
1	"NO NOISE" Model NN3-F Hellberg	93	13.92	0.77	1152.42	277.31	Used long time
2	Mark IV MSA	12	13.60	0.73	1277.00	417.00	Used long time
3	Peltor H7P3e	3	14.50	0.58	933.33	52.04	Almost new
4	David Clark	1	14.50	-	450.00	-	Almost new
	$\Sigma(2 - 4)$	16	13.89	0.76	1153.67	301.50	

Note: N* - Population

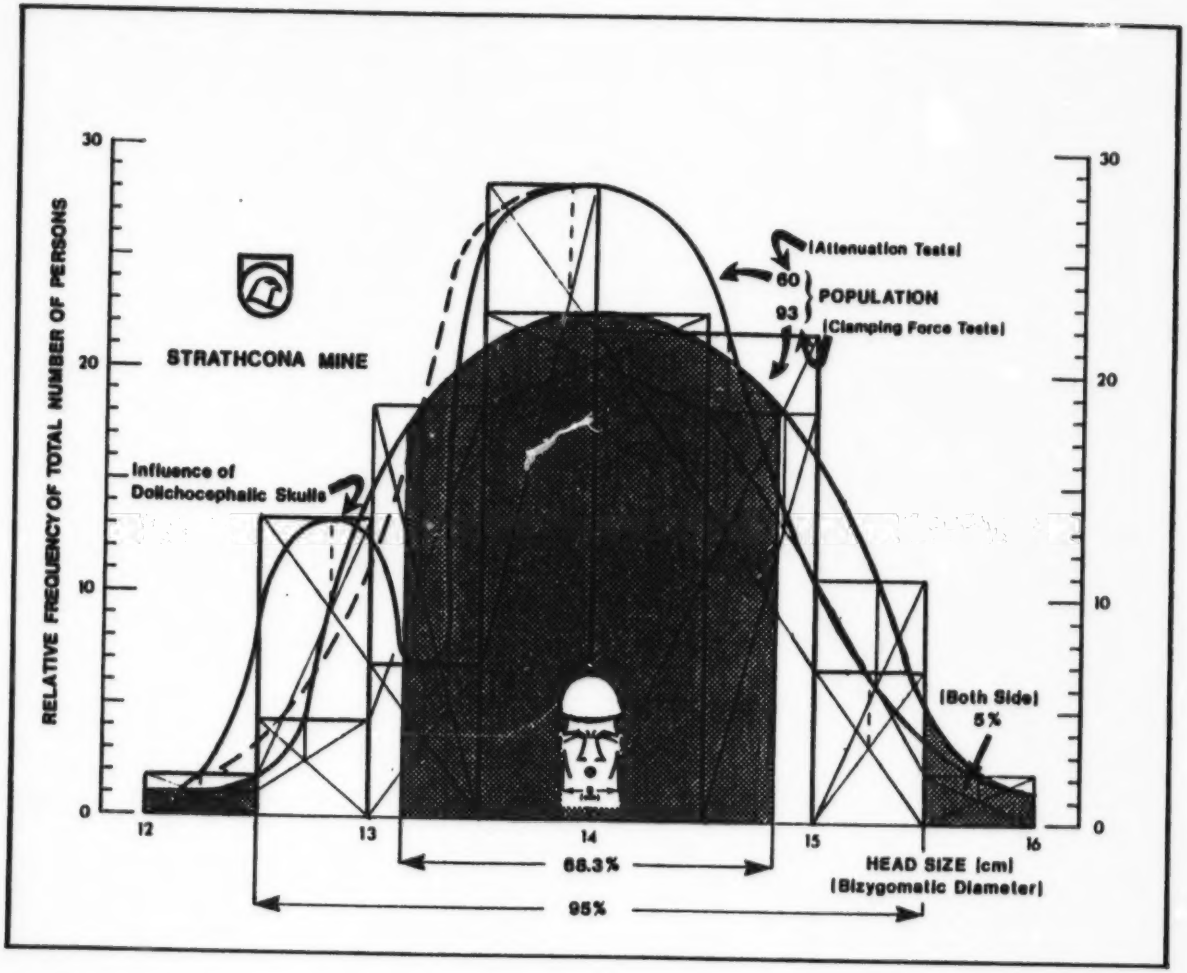

Fig. 1 - This bimodal frequency curve has two maxima: the first maximum is related to dollichocephalic skulls; and the second maxima is related to the curve's positive skewness (population 60). The flatter curve is considered to be platykurtic (population 93).

results. Moreover, we must work toward providing hearing protection for workers with head sizes ranging from 12 cm to 16 cm. In other words, we must secure a means whereby clamping force would remain almost constant over this range. The constructed platykurtic curve points us in that direction. In this country there are 250,000 cases with noise related disability, or 1% of the entire population. That is why we must not allow workers, whose head sizes are in the extremes, to suffer by losing their hearing from improper protection. An ear muff whose clamping force remains constant, or relatively constant, should be constructed to protect all workers equally.

The clamping force frequency curve has negative skewness (skewed to the left but only gently) (Figure 2). It is almost a normal curve. From this frequency curve it can be concluded that 85% of the work force has a clamping force greater than 1000 (gwt), which is a very good result for a large mine such as this one. By the same token, it is evident that deterioration of ear muffs is slow. This conclusion is backed by the bar graphs in Figure 3. From these graphs of clamping force versus head size, it can also be seen that ear muff deterioration is exascerbated by the population with head sizes of 13.5 cm to 14.0 cm. Also it can be seen that clamping force increases with head size.

Data from Appendix A was used to construct a standard deviation ellipse (see Figure 4). The ellipse in large part covers the field of head size versus ear muff clamping force, and we can therefore expect good but still incomplete attenuation.

LHD equipment is widely used at this mine. Frequency analyses were performed at the engine of a scooptram S-4A and at the operator's ear. The results were as follows:

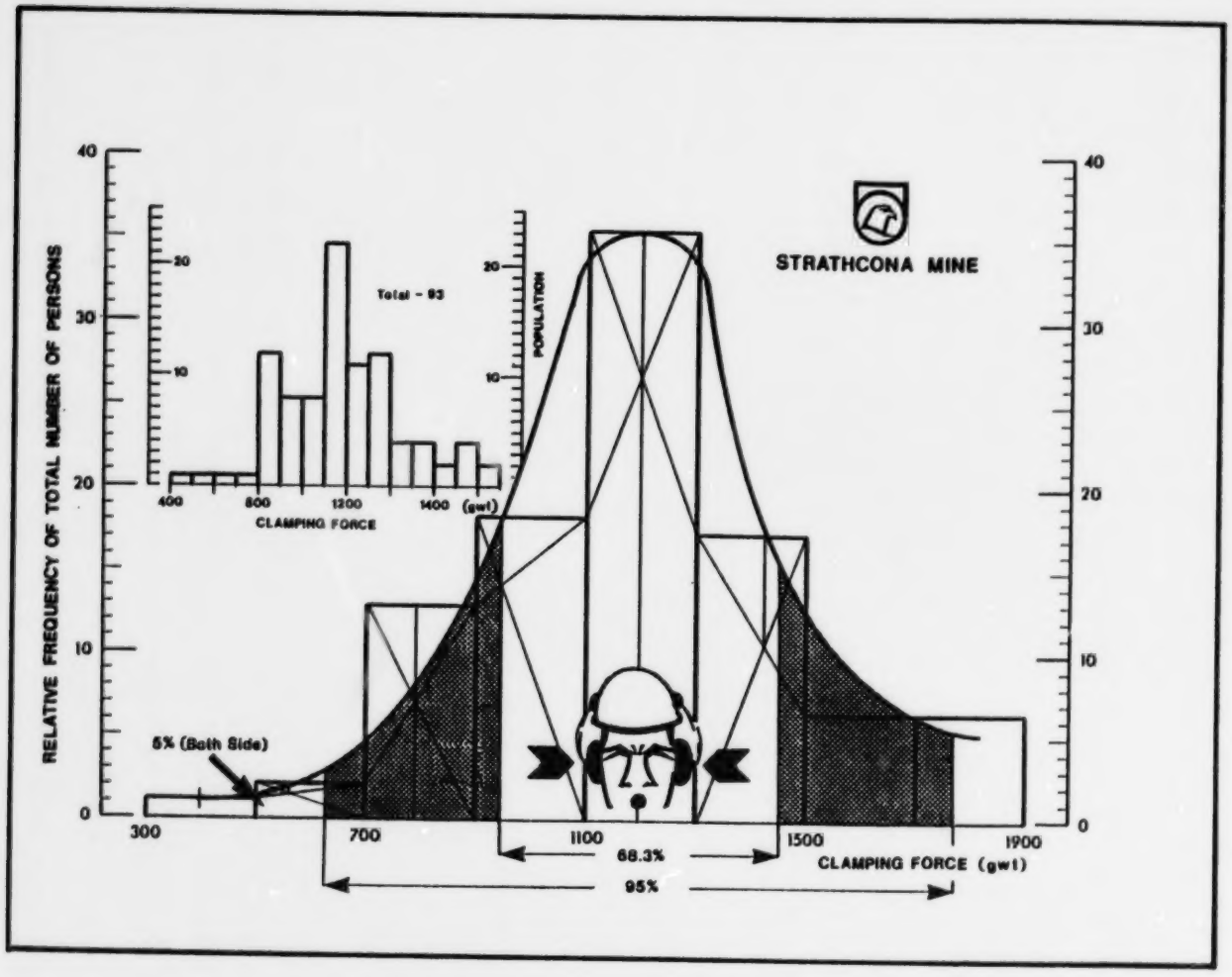

Fig. 2 - The clamping force frequency curve (note its skewness).

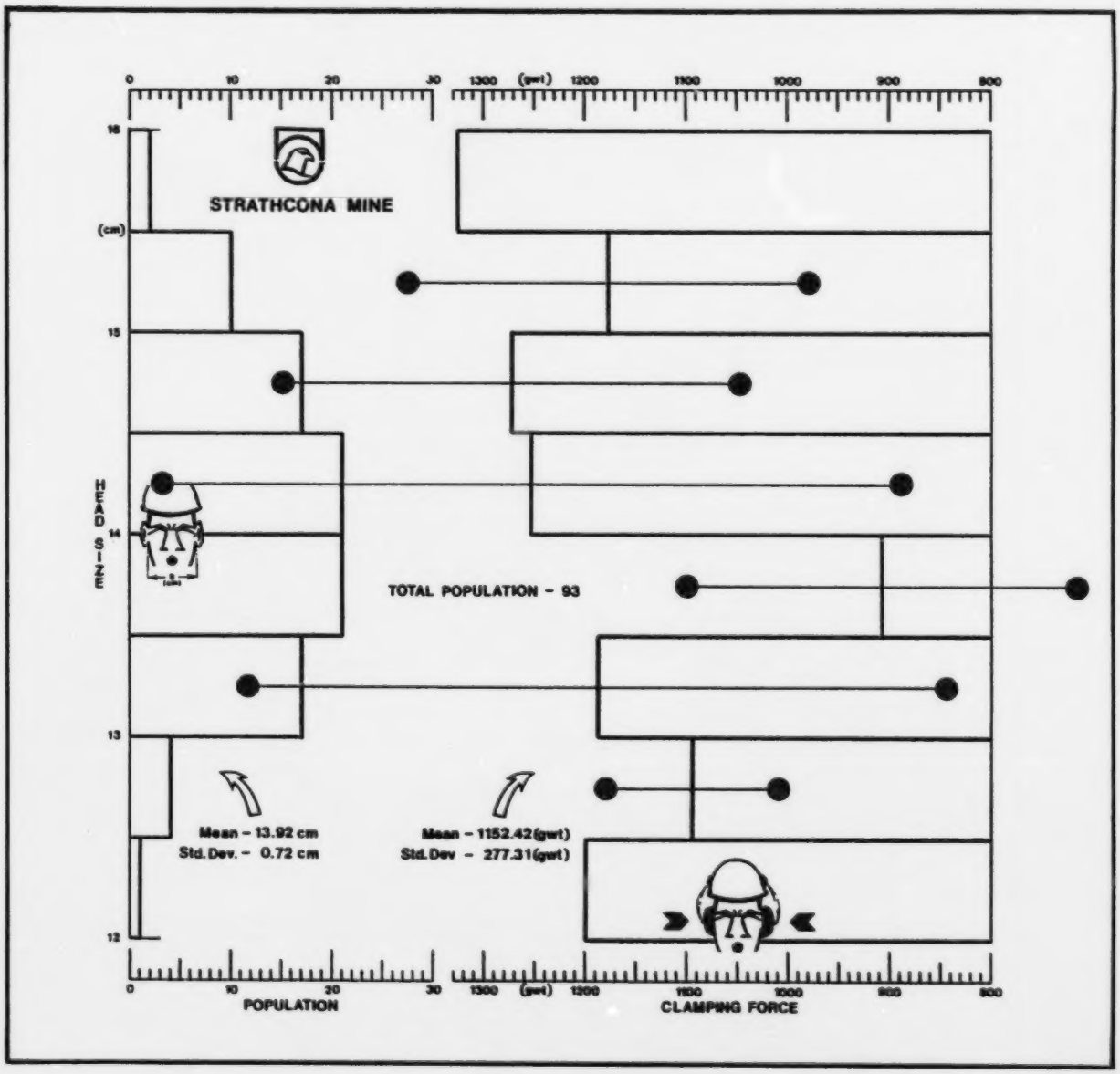

Fig. 3 - Relationships between head size and clamping force at the Strathcona Mine.

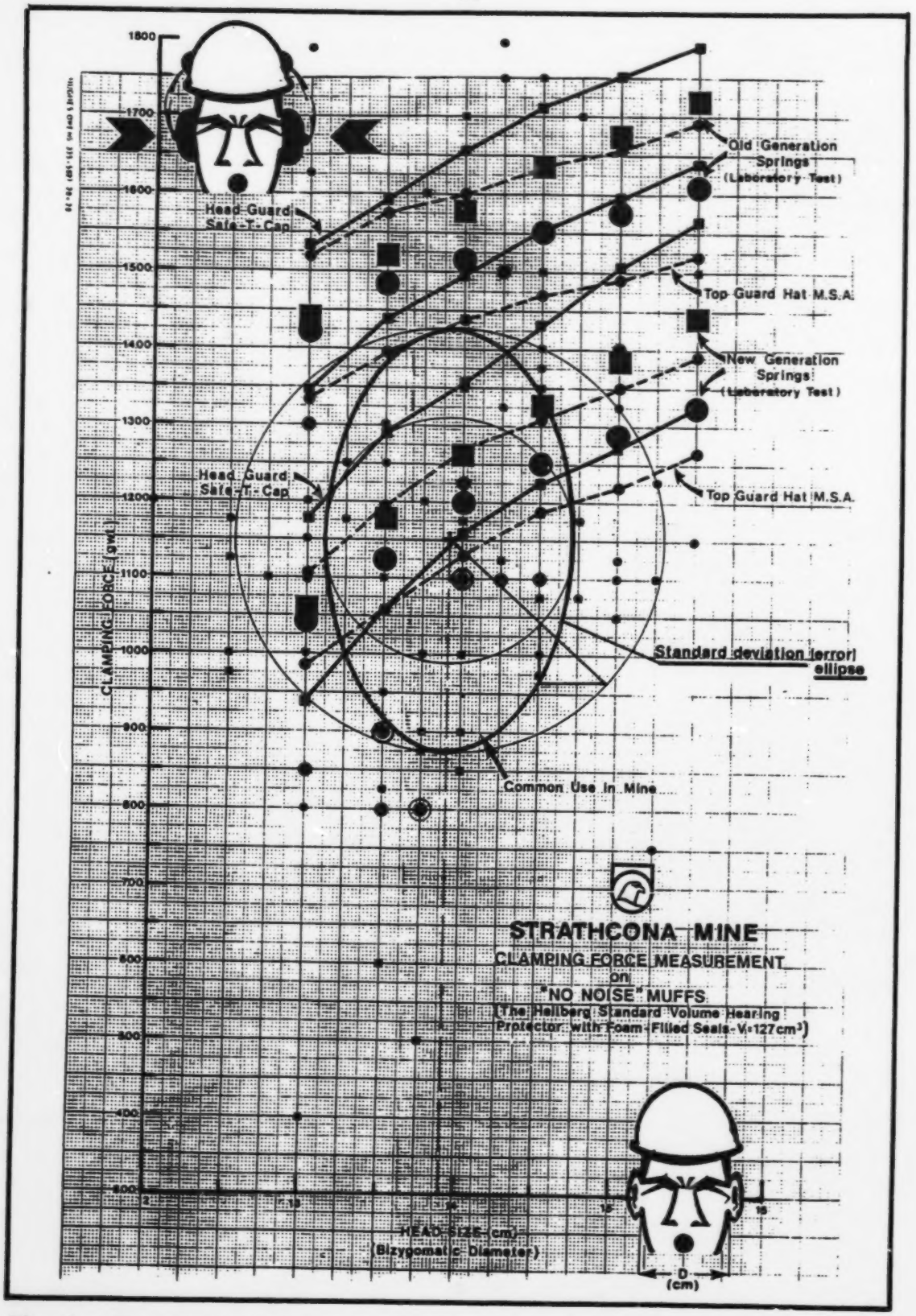

Fig. 4 - The standard deviation (error) ellipse of "NO NOISE" muffs at the Strathcona Mine.

Status	Frequency Hz - dB							dBA	dBC
	125	250	500	1k	2k	4k	8k		
At engine, average of both sides (1 m)	115.5	113.6	109.6	101.6	101.5	100.0	94.88	110.70	118.1
At operator's ear	107.75	103.25	99.5	94.5	92.5	88.75	82.25	101.25	112.2

The following equation can be used to estimate the sound level (dBA) at a worker's ear when he is wearing a personal hearing protector:

$$dBA = dBC - (NRR - 10)$$

where, dBC is the C-weighted sound level to which the operator is exposed; NRR is the Noise Reduction Rating of the protector; and 10 is a factor, based on "real world" conditions, used to "derate" the NRR. Based on this equation, the sound level at an operator's ear (in dBA) when he is working at a location where the sound level is 112.20 dBC, and using a personal hearing protector rated at NRR = 24, would be 98.2 dBA. Noise over ear muffs is 101.25 dBA. Theoretical attenuation would be only 3.05 dBA.

On the basis of six measurements, attenuation was 4.62 dBA, which is greater than theoretical attenuation by 1.57 dBA. Where low frequencies prevail ear muff efficiency is poor. Attenuation could be increased further by using ear plugs.

EAR MUFF CONDITION

Ear muffs were in good condition (Table 3). Here too, workers had a tendency to bend the springs of "NO NOISE" ear muffs in order to improve their comfort. In Figures 3 and 4 it can be seen that workers with head sizes from 13.5 cm to 14.0 cm did the most bending, though it is also true that they comprise the largest population.

This test, however, shows that more effort must be made to improve ear

Table 3 - Tests of ear muff conditions in mines and mills

No.	Ear Muff	N*	Ear Muff Conditions					
			Good		Fair		Poor	
			N_1	Percent	N_2	Percent	N_3	Percent
1	"NO NOISE" (NN3-F)	93	71	76.34	14	15.05	8	8.60
2	Mark IV, MSA	12	6	50.00	5	41.67	1	8.33
3	Peltor (H7P3e)	3	1	33.33	1	33.33	1	33.33
4	David Clark Model E-705 Straightaway	1	0	0.00	1	100.00	0	0.00
1-4	Σ	109	78	71.56	21	19.27	10	9.17

Note: * - Population ($N^* = N_1 + N_2 + N_3$)

muff conditions because 9% of them were deemed to be in poor shape.

ATTENUATION MEASUREMENTS

Attenuation measurements were performed on the following ear muffs:

1) "NO NOISE", model NN3-F, 39 measurements in OSHA mode (Appendix B), and 36 measurements in ISO mode (Appendix C);
2) Mark IV, MSA, 8 measurements in OSHA mode (Appendix D); and 10 measurements in ISO mode (Appendix E);
3) Peltor H7P3e, 2 measurements in OSHA model (Appendix D); and 2 measurements in ISO mode (Appendix E); and
4) Bilsom Viking Muff 2314, 1 measurement in OSHA mode (Appendix D), and 1 measurement in ISO mode (Appendix E).

Tests of "NO NOISE" ear muffs show that they have the following attenuation (Appendices B and C):

Mode	Characteristic	dBA	Confidence Limit	
			90%	95%
OSHA	Mean Std. Dev.	12.97 5.76	12.97±1.8 dBA	12.97±2.2 dBA
ISO	Mean Std. Dev.	13.10 6.38	13.10±2.0 dBA	13.10±4.0 dBA

At the Strathcona Mine almost 98% of the miners wear ear plugs, especially the yellow foam plugs made by E.A.R. which have a NRR of 29 dBA. Complaints about ear muffs are frequent: it hurts behind the ears when glasses are worn; they are uncomfortable in hot areas; when the head moves the muffs also move and must constantly be readjusted, etc. Because of these complaints many workers choose to use only ear plugs. At the Strathcona Mine, mainly "NO NOISE" muffs are used. 78% of the test group wore them. The best

attenuation achieved with these was 24.6 dBA. Many of the workers wear both ear plugs and muffs, though a few insist they cannot tolerate ear plugs*.

COMFORT OF EAR MUFFS

Good attenuations were demonstrated by Peltor ear muffs, but only on two occasions (Appendices D and E). At the time, they were fairly new, and so it would be unwise to draw conclusions from these two measurements alone.

Overall comfort was not the best. This is to be expected since the error ellipse points to the existence of limited efficiency (Figure 4). Comfort grading results are given in Table 4. If we compare these results with those in Figure 4, we can determine the precise relationship which exists between clamping force and comfort. The integrated ellipse gives the following results:

1) 56.8% of the ellipse's surface area covers the field of clamping force versus head size.
2) 43.2% of the ellipse's surface area does not cover the field of clamping force versus head size.

From Table 4, 54.2% of the workers deemed comfort satisfactory. Attenuation and comfort are in an inverse relationship.

Using Appendices B and C, measurement results were calculated for L_{max} and L_{peak} levels (Table 5). The aim was to see how big the "peaks" are, which according to some authorities, stimulate loss of hearing (2). Measurements were made with an integrating sound level meter, B & K, type 2225. Instrument control was performed to find means of standard deviations for L_{max} and L_{peak}. Result confidences are as follows:

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*This discovery was investigated by the Occup. Health Nurse, Bev Harris, and remedied.

Table 4 - Comfort of ear muffs in mines and mills

No.	Ear Muff	N*	○ -Satisfactory		◒ -Good		◍ -Very Good	
			N_1	Percent	N_2	Percent	N_3	Percent
1	"NO NOISE" (NN3-F)	46	29	63.0	17	37.0	0	0.0
2	Mark IV, MSA	10	3	30.0	7	70.0	0	0.0
3	Peltor (H7P3e)	2	0	0.0	1	50.0	1	50.0
4	Bilsom No. 2314	1	0	0.0	1	100.00	0	0.0
1-4	Σ	59	32	54.24	26	44.07	1	1.69

Note: * Population ($N^* = N_1 + N_2 + N_3 + N_4$)

Confidence Limit			
90%		95%	
L_{max}	L_{peak}	L_{max}	L_{peak}
4.51±1.35 dBA	5.0±1.66 dBA	4.51±1.66 dBA	5.00±1.16 dBA

From these results we can see that the measurements were very precise (±1.5 dBA). This is better than predicted for the Type 2 Sound Level Meter ±2 dBA (overall tolerance) (3).

CONCLUSIONS

Measurements have shown that the attenuation of "NO NOISE" muffs at the Strathcona Mine is about 13 dBA. For each type of machine the dBA or dBC or peak frequency range should be obtained so that the theoretical efficiency of ear muffs can be ascertained. The overall condition of ear muffs is fairly good, but it should be noted that 8.6% of them were found to be in poor condition. To make an improvements, cushions should be replaced more often and the bending of spring-loaded arms should be controlled. The employer should ensure that workers are trained correctly in properly fitting ear muffs. Head shapes and sizes had a marked effect on attenuation, as did job function (e.g., how much head turning is required at specific jobs). Physical obstruction (e.g., eye glasses) weakened attenuation. Because scooptrams are widely used in the mine, it was possible to demonstrate theoretical attenuation of 3 dBA. Noise under ear muffs come out to about 98 dBA. If we wished to attenuate the high levels of noise to below 90 dBA using ear plugs in conjunction with muffs would not be sufficient. Ear muffs alone are not a complete solution to the attenuation of noise.

Ear muff control should be continued, by measuring head size and clamping force with the apparatus suggested in the main report.

Table 5 - Peak levels in mining, milling and smelting operations at the Strathcona and Falconbridge Mines.

Falconbridge - Strathcona

Instrument: Bruel and Kjaer Integrating Sound Level Meter Type 2225.

No.	Sound Source	dBA L_{max} Mean Std. Dev.	dBA L_{peak} Mean Std. Dev.	Δ	N
1	Jack Leg Drill	118.65 3.36	134.85 5.68	16.3	11
2	Stoper Drill - Rock Bolter	118.51 5.92	135.0 7.0	16.5	22
3	Jumbo Drill - two booms	116.96 5.91	122.14 5.91	15.19	8
4	Long Hole Drill	119.19 1.98	135.08 2.59	15.89	4
5	Long Tom Drill - two booms	120.27 2.99	137.17 4.63	16.9	23
6	ITH In the Hole Drill	98.27 5.12	116.25 5.66	17.98	7
7	Diamond Drill	104.02 4.76	120.81 9.93	16.79	7
8	Mucking Machine	106.58 3.60	121.53 3.53	14.95	4
9	Bolting Machine	-	-	-	-
10	Air Plugger (Brk. Cement)	-	-	-	-
11	Slusher	97.50 4.99	111.35 4.45	13.85	4
12	Scooptram	106.55 14.37	123.33 11.80	16.78	12
13	Conveyor Man	94.83 6.40	112.15 8.35	17.32	3
14	Chute Puller	114.80 9.19	133.15 3.32	18.35	2
15	Vent. Fan - 38" 60 HP	-	-	-	-
16	Primary Crusher - U/G Jaw Crush.	102.34 6.93	121.56 8.24	19.22	8
17	Secondary Crusher	91.77 1.33	106.27 1.62	14.5	3
18	Tertiary Crusher	95.45 0.21	108.35 0.64	12.9	2
19	Ball Mill	93.20 2.02	107.57 1.16	14.37	3
20	Flotation Op. Area	85.9	99.3	13.4	1
21	Compressor Room	89.7	103.0	13.3	1
22	Power House	94.5	107.5	13.0	1
23	Electrostatic Precipitator	93.65 0.35	109.20 3.82	15.55	2
24	Converter Puncher	99.13 1.10	114.27 1.79	15.14	3
25	Converter Skimmer - Fluxing	89.47 4.76	103.83 4.91	14.36	3
		Mean$_{25}$ Std. Dev.	Mean$_{25}$ Std. Dev.		
		4.31	5.00		
◇ 19		3.45	3.04	19 ◇	

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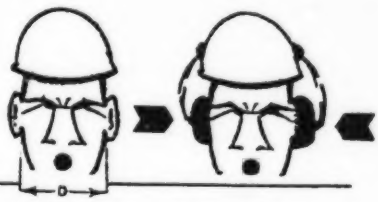
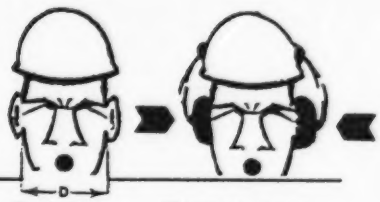
Appendix A

Head size and clamping force data of "NO NOISE" Model NN3-F ear muffs



No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	1	13.75	800
2	Driller	1	13.00	1300
3	Driller	1	14.50	1350
4	Driller	1	15.25	1100
5	Driller	1	15.50	1150
6	Driller	1	12.50	975
7	Driller	1	13.75	900
8	Driller	2	13.75	800
9	Driller	1	14.00	900
10	Driller	2	13.00	850
11	Driller	2	14.25	1750
12	Driller	3	13.75	500
13	Driller	1	13.75	875
14	Driller	2	13.50	800
15	Driller	2	15.25	750
16	Driller	1	14.50	1500
17	Driller	2	14.25	1100
18	Driller	1	14.50	1075
19	Long Hole Driller	1	15.50	1500
20	Long Hole Driller	1	13.00	1300
21	Long Hole Driller	1	13.00	1450
22	Long Hole Driller	3	13.50	1250
23	Long Hole Driller	1	12.50	1125
24	Long Hole Driller	1	12.75	1100
25	Long Hole Driller	1	13.75	1000
26	Long Hole Driller	1	13.50	900
27	Jumbo Driller	1	14.50	1100
28	Jumbo Driller	1	13.75	1200
29	Jumbo Driller	1	13.50	1300
30	Jumbo Driller	2	13.00	850
31	Diamond Driller	1	14.30	975
32	Driller Scooptram	1	14.50	1400
33	Driller Scooptram	3	13.75	800
34	Driller Scooptram	3	15.00	1125
35	Driller Scooptram	1	14.50	1300
36	Driller Scooptram	1	14.50	1000
37	Driller Scooptram	2	13.00	1000
38	Driller Scooptram	1	12.50	1175
39	Driller Scooptram	1	13.50	900
40	Stope Boss	3	13.00	400
41	Stope Boss	1	14.25	1100
42	Stope Boss	1	14.50	1350
43	Training	1	14.75	1075
44	Timberman	2	13.50	600
45	Timberman	1	14.00	1100
46	Pipefitter	1	14.00	1250
47	Pipefitter Helper	1	13.50	825
48	Trackman	1	13.00	1625

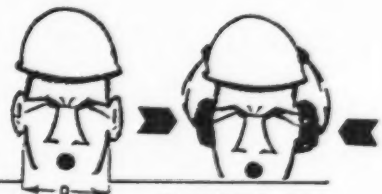
Cont. overleaf



No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
49	Scooptram	1	13.00	1150
50	Scooptram	1	13.00	1200
51	Motorman	1	15.00	1100
52	Motorman	1	14.50	1225
53	Nipper	1	14.00	1100
54	Nipper	1	13.50	1100
55	Ore Pass Fender	1	14.75	1175
56	Ramp Haulage	1	13.00	1300
57	Blaster Helper	1	15.25	1225
58	Diesel Mechanic	3	13.50	800
59	Diesel Mechanic	3	15.00	1050
60	Diesel Mechanic	2	14.00	1700
61	Diesel Mechanic	1	14.00	1225
62	Diesel Mechanic	1	13.00	1625
63	Diesel Mechanic	1	14.00	1225
64	Mechanic	2	13.50	900
65	Mech. Foreman	1	13.25	1300
66	Electrician	1	14.25	1325
67	Electrician	1	13.00	1100
68	Construction	1	14.00	1100
69	Construction	1	15.00	1400
70	Construction	1	14.50	1375
71	Construction	1	14.00	1200
72	Bonus man	1	14.50	1750
73	Bonus man	1	14.25	1500
74	Level Cleaner	1	14.00	1350
75	Level Cleaner	1	14.00	1000
76	Level Cleaner	1	14.50	1175
77	Vent. Technician	1	15.00	1400
78	Vent. Technician	1	15.00	1325
79	Vent. Technician	1	13.50	950
80	Shaft Inspector	2	14.75	1700
81	Shaft Inspector	3	14.00	850
82	Safety Supervisor	1	14.25	1125
83	Safety Advisor	1	13.50	1300
84	Shift Boss	2	13.50	900
85	Shift Boss	1	14.25	1500
86	Surveyor	1	14.00	1100
87	Surveyor	1	15.00	1300
88	Surveyor	1	13.25	1175
89	Geologist	1	13.25	1250
90	Ground Control	1	14.25	1800
91	Mine Captain	1	12.00	1200
92	Mine Captain	2	14.50	1100
93	Mine Captain	1	13.00	800
	Mean:		13.92	1152.42
	Std. Dev.:		0.77	277.31

Note: 1 - Good; 2 - Fair; 3 - Poor.

Head size and clamping force data of three different muffs: MSA Mark IV; Peltor H7P3e; and David Clark, Model E-705



MARK IV MUFFS

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	1	14.00	1300
2	Long Hole Driller	1	13.50	1225
3	Long Hole Driller	2	13.00	1350
4	Driller Scooptram	2	14.25	950
5	Stope Boss	1	14.25	1200
6	Nipper	3	14.75	1900
7	Diesel Mechanic	2	14.00	900
8	Mechanic	2	12.50	1100
9	Level Cleaner	2	14.00	1025
10	Bonus Man	1	12.00	900
11	Surveyor	1	12.50	925
12	Safety Advisor	1	13 50	1950
	Mean:		13.60	1277.00
	Std. Dev.:		0.73	417.03

PELTOR MUFFS (H7)

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Stope Boss	1	14.50	875
2	Level Cleaner	3	14.50	975
3	Ventilation Man	2	13.50	950
	Mean:		14.17	933.33
	Std. Dev.:		0.58	52.04

DAVID CLARKE MUFFS

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Diamond Drill Foreman	2	14.50	450
Σ	Mean:		13.89	1153.67
	Std. Dev.		0.76	301.50

Note: 1 - Good; 2 - Fair; 3 - Poor.

Attenuation tests of "NO NOISE", Model NN3-F, the Hellberg standard volume hearing protector - OSHA mode

No.	Equipment	Comfort	L_{OSHA} (dBA)	Attenuation (dBA)			L_{OSHA} (dBA)		LISO (dBA)				Comments	Location
				L.S.	R.S.	B.S.	Max	Peak	L_{eq} (60s)	Slow	Fast	Peak		
1	Stoper Dr. Rock Mtg.	○	14.0	110.8	18.4	19.4	18.9	118.6	136.0	115.4	117.0	117.4	132.5		2600 Level
2	Stoper Dr. Rock Mtg. (Y. Rivard)	◒	13.5	106.9	23.2	17.4	20.3	117.55	>141.7	118.2	117.8	119.3	132.2	Outside meas. too low	2500 Level
3	Stoper Dr. Rock Mtg. (J. Regis)	○	15.0	-	-	-	-	-	-	118.2	117.8	119.3	132.2	Maltune. Metros dB-307	2500 Level
4	Stoper Dr. Rock Mtg. (H. Lapointe)	○	13.75	111.1	15.0	8.5	11.8	119.2	137.2	116.4	119.4	119.4	131.3	LISO - common meas.	2500 Level
5	Stoper Dr. Rock Mtg. (Y. Briton)	○	13.75	114.0	10.2	9.6	9.9	118.2	135.7	116.4	119.4	119.4	131.3		2500 Level
6	Stoper Dr. Rock Mtg. (B. Ekenhour)	◒	12.50	116.6	12.8	20.3	16.6	125.35	143.0	114.9	120.4	121.2	136.4		1800 Level
7	Stoper Dr. Rock Mtg. (A. Joulet)	◒	13.75	115.8	12.2	12.7	15.5	119.5	137.1	118.1	118.8	120.0	135.0		1800 Level
8	Stoper Dr. Rock Mtg. (R. Seguin)	○	14.5	115.0	19.8	-	-	113.8	135.0	117.7	117.9	116.1	134.7	Wore plugs RE dB-307 affected by humidity	2400 Level
9	Stoper Dr. Rock Mtg. (Y. Viens)	○	12.25	115.4	15.0	15.0	15.0	119.0	138.7	118.8	118.5	118.2	131.8		2700 Level
10	Stoper Dr. Rock Mtg. (R. Gervais)	○	12.5	109.0	28.8	14.8	21.8	116.0	-	118.2	118.7	118.5	131.8		2700 Level
11	Jumbo Dr. (Elec. Hydr.) (D. Bertrand)	◒	14.5	100.6	>19.5	>21.7	>20.6	107.1	121.6	102.4	103.4	102.7	113.5	Borrowed muffs	2600 Level
12	Jumbo Dr. (Elec. Hydr.) (M. Pelletier)	◒	13.0	94.7	>17.8	4.2	>11.0	102.6	120.0	101.2	96.9	95.6	113.9	Operator struggling primarily 1 boom op.	1800 Level
13	Long Hole Drill (L. Rivest)	◒	14.5	119.1	10.5	14.6	12.6	126.9	>145.3	116.6	117.6	117.4	131.5		2700 Level
14	Long Hole Drill (G. Bellanger)	○	13.5	117.5	4.5	3.3	3.6	119.5	138.1	118.6	117.6	118.0	132.7	Pads flat - supplied new cushions	2200 Level
15	Long Hole Drill (S. Cthier)	○	14.25	116.9	10.6	8.2	9.4	119.6	142.2	-	-	-	-		2200 Level
16	Long Tom Drill (2 boom)(D. Lamb)	◒	13.0	118.6	19.7	18.9	19.3	-	-	111.4	114.9	115.1	129.6	Plugs & muffs worn	2700 Level
17	Long Tom Dr. (2 boom)(D. Bessserer)	◒	14.5	117.6	19.8	13.0	16.4	125.4	136.8	118.0	117.2	117.5	132.7	Plugs & muffs worn	2700 Level
18	Long Tom Dr. (2 boom)(Y. Rivard)	◒	13.5	119.2	17.9	23.0	20.5	124.85	143.9	121.2	119.2	120.1	133.5		2500 Level
19	Long Tom Dr. (2 boom)(J.P. Regis)	○	15.0	118.2	17.1	17.2	17.2	122.8	144.3	121.3	121.6	121.8	136.1		2500 Level
20	Long Tom Dr. (2 boom)(L. MacDonald)	-	13.26	113.0	18.3	15.2	16.8	117.75	137.5	114.5	116.1	115.6	129.4	Only 1 boom operating	2425 Level
21	Long Tom Dr. (2 boom)(R. Lapensee)	○	13.5	>115.0	>2.5	>4.7	>3.6	-	-	121.6	120.6	121.9	135.2		2300 Level

Cont. overleaf

No.	Equipment	Comfort		L_{OSHA} (dBA)	Attenuation (dBA)			L_{OSHA} (dBA)		L_{ISO} (dBA)				Comments	Location
					L.S.	R.S	F.S.	Max	Peak	L_{eq} (60s)	Slow	Fast	Peak		
22	Long Tom Dr. (2 boom)(M. Lafleur)	○	14.5	>104.9	2.2	17.5	>4.9	118.35	137.6	-	-	-	-	Drilled 2 holes only	2600 Level
23	Long Tom Dr. (2 boom)(W. Beaudry)	○	14.0	118.2	17.9	17.9	17.9	121.0	141.4	116.8	116.4	116.4	131.7		2600 Level
24	ITH In the Hole Drill (P. Audette)	○	14.5	98.9	>18.9	>18.9	>18.9	102.2	121.6	101.0	99.7	99.6	115.7	Plugs and muffs worn	1200 Level
25	ITH In the Hole Drill (R. Lamothe)	○	12.75	92.7	>13.7	>11.6	>12.7	96.7	<120.0	93.2	93.5	93.6	111.0	Eqipped with muff but only plugs worn	2900 Level
26	Diamond Drill (L. Laporte)	◒	15.0	100.8	13.9	>20.4	>17.2	102.7	>121.5	97.6	98.4	97.5	109.7	Good muffler on motor and pump	2600 Level
27	Diamond Drill (C. Gratton)	◒	12.5	105.5	>23.5	14.0	18.8	110.7	128.4	108.7	107.6	107.6	121.0		2600 Level
28	Diamond Drill (N. Rhyno)	◒	15.0	107.0	>27.1	>26.9	>27.0	110.3	123.5	105.7	106.9	106.6	118.7	V. noisy ventilation	2600 Level
29	Conveyor Man (C. Mazgai)	○	14.75	96.2	+1.2	+3.1	+2.2	100.1	<120.0	96.5	96.3	96.4	109.7	B-Conveyor, much vib.	2900 Level
30	Chute Puller (L. Lapointe)	○	-	99.6	8.5	7.3	7.9	118.3	137.1	107.2	108.5	108.3	130.8	2 diff. chutes used	2900 Level
31	Scooptram ST-5 (F. Belanger)	○	14.5	104.0	7.9	4.7	6.3	-	-	-	-	-	-		2700 Level
32	Scooptram (R. Lamothe)	○	12.75	101.5	4.3	2.6	3.5	-	-	102.3	102.8	101.0	120.5	Loading truck	2900 Level
33	Scooptram (A. Leblanc)	○	12.5	102.3	5.3	3.3	4.3	110.15	141.6	-	-	-	-		2500 Level
34	Scooptram ST-2 (L. Morin)	○	13.5	97.4	13.6	>15.5	>14.6	106.15	>139.9	92.2	92.5	93.7	111.5	SLM readings diff. to obtain - lower than ac.	2300 Level
35	Scooptram ST-5 (G. Plamondon)	◒	13.0	97.5	>16.5	>18.5	>17.5	117.4	>141.9	95.5	98.2	98.0	115.8	Remote loading, - wears plugs - borrowed muffs	2300 Level
36	Scooptram Elec. (C. Claudette)	○	13.5	91.2	>6.8	>11.8	>9.3	102.3	>136.1	84.5	88.0	88.3	110.2	Wears plugs only	1800 Level
37	U/G Jaw Crusher (M. Morin)	○	14.0	97.8	+1.7	0.6	+0.6	107.65	130.7	97.2	96.5	97.0	114.7	Wears plugs only, muff useless when head turns	2700 Level
38	U/G Jaw Crusher (E Labranche)	◒	13.5	99.3	4.3	3.6	4.0	112.9	134.0	98.4	96.6	95.0	113.4	Plugs and muffs worn	3000 Level
39	U/G Jaw Crusher (R. Denomme)	○	14.25	98.3	9.6	7.9	8.8	108.15	130.4	99.1	99.4	98.9	118.6		3000 Level
	Mean		13.75	107.38	13.40	11.83	12.97	114.08	135.36	109.00	109.50	109.55	124.99		
	Std. Dev.		0.82	8.93	6.47	6.27	5.76	8.13	6.59	10.17	10.49	10.71	9.61		

Note: ○ Satisfactory; ◒ Good; ● Very Good

Undetermined number (>No.; <No. and ±No.) are not in Mean value.

Attenuation tests of "NO NOISE", Model NN3-F
the Hellberg standard volume hearing protector - ISO mode

No	Equipment	Comfort		L_{ISO} (dBA)	Attenuation (dBA)			L_{ISO} (dBA)		L_{OSHA} (85) (dBA)	Comments	Location
					L.S.	R.S.	B.S.	Max	Peak			
1	Jack Leg Drill (A. Goulet)	◒	13.75	115.3	10.0	16.1	13.1	122.0	140.35	<114.5		1800 Level
2	Jack leg Drill (B. Fisenhour)	◒	12.50	115.6	8.7	16.9	12.8	119.5	>142.7	113.8		1800 Level
3	Stoper Dr. Rock Mtg. (Y. Viens)	○	12.25	117.3	15.0	14.9	14.95	120.6	140.75	-		2700 Level
4	Stoper Dr. Rock Mtg. (Y. Briton)	○	13.75	115.1	12.8	12.3	12.55	119.2	136.75	112.9		2700 Level
5	Stoper Dr. Rock Mtg. (H. Lapointe)	○	13.75	116.9	18.2	19.0	18.6	121.2	140.1	-		2700 Level
6	Stoper Dr. Rock Mtg. (R. Gervais)	○	12.50	114.7	-	16.4	-	-	118.7	-		2300 Level
7	Stoper Dr. Rock Mtg. (J. Regis)	○	15.01	116.5	10.5	21.23	15.87	121.0	>144.6	104.5		2500 Level
8	Stoper Dr. Rock Mtg. (Y. Rivard)	◒	13.50	113.85	18.5	26.0	22.25	120.0	139.5	-		2500 Level
9	Stoper Dr. Rock Mtg.	○	14.00	116.6	29.13	18.33	23.73	119.7	136.8	-		2600 Level
10	Long Hole Dr. (L. Ethier)	○	14.25	118.25	17.2	8.4	12.8	119.5	135.6	>115.0		2225 Level
11	Long Hole Dr. (G. Belanger)	○	13.50	119.75	19.6	20.9	20.25	121.85	138.5	>115.0	Pads flat - supplied new cushions	2225 Level
12	Long Hole Dr.	◒	14.50	118.25	6.6	18.6	12.6	124.35	144.25	>114.4		2700 Level
13	Jumbo Dr. (Elec. Hydr.) (M. Pelletier)	◒	13.25	94.2	11.2	7.2	9.2	104.4	122.05	99.6	Atlmac	1825 Level
14	Jumbo Dr. (Elec. Hydr.)	◒	14.50	104.3	>24.5	>24.8	>24.6	108.0	130.1	-	Atlas Copco	2600 Level
15	Long Tom Drill (W. Boudrie)	○	14.00	119.25	8.6	23.7	16.15	121.6	140.05	113.75		2600 Level
16	Long Tom Drill (M. Latleur)	○	14.50	119.5	19.3	22.7	21 00	121.5	140.05	113.53		2600 Level
17	Long Tom Drill (L. McDonald)	○	13.25	114.2	16.8	17.2	17.00	118.5	137.35	94.49	Only one boom operating	2325 Level
18	Long Tom Drill (J.P. Regis)	○	15.0	119.25	14.3	17.2	15.75	123.3	141.1	117.0		2500 Level
19	Long Tom Drill (Y. Rivard)	◒	13.50	119.1	15.1	27.0	21.05	126.0	143.9	116.1		2500 Level
20	Long Tom Drill (D. Beaserer)	◒	14.50	118.75	16.1	12.8	14.45	119.6	<145.5	-	Wears plugs and muffs	2700 Level

Cont. overleaf

No.	Equipment	Comfort		L_{ISO} (dBA)	Attenuation (dBA)			L_{ISO} (dBA)		L_{OSHA} (85) (dBA)	Comments	Location
					L.S.	R.S.	B.S.	Max	Peak			
21	Long Tom Drill (D. Lamb)	◒	13.00	111.9	19.7	3.9	11.8	-	-	-	Wears plugs and muffs	2700 Level
22	Long Hole Drill ITH (G. Fortier)	○	12.75	92.35	>11.3	>13.4	>12.35	94.0	<120.0	93.23	Very quiet drill	1225 Level
23	Long Hole Drill ITH (P. Audette)	○	14.50	99.8	>19.0	>20.6	>19.8	104.0	123.2	101.55	V. quiet drill - plugs & muffs worn	1225 Level
24	Diamond Drill (B. Rhyno)	○	15.00	104.15	>26.2	20.0	>23.1	108.7	122.05	106.5	V. noisy ventilation in this area	2625 Level
25	Diamond Drill (C. Gratton)	◒	12.5	107.75	26.8	14.27	20.5	-	-	107.4		2625 Level
26	Diamond Drill (L. Laport)	◒	15.0	101.8	>21.3	15.7	>18.5	108.1	140.35	97.5		2526 Level
27	Shute Puller (L. Lapointe)	○	-	103.35	9.4	6.9	8.15	121.3	135.5	104.4	2 different chutes involved in test	2900 Level
28	Conveyor Man (C. Mazgai)	○	14.75	96.0	0.37	3.1	1.7	100.3	121.45	95.5	B-conveyor - much vibration here	2900 Level
29	Scooptram ST-5 (C. Claudette)	○	13.5	92.15	>11.7	7.3	>9.5	103.95	127.6	-	Wears plugs only	1825 Level
30	Scooptram ST-5 (G. Plamondon)	◒	13.0	102.5	5.2	9.0	7.1	115.8	134.25	114.75	Remote loading - wears plugs - borrowed muffs.	2300 Level
31	Scooptram ST-5 (L. Morin)	○	11.5	99.0	17.0	15.0	16.0	142.45	128.9	-		2325 Level
32	Scooptram ST-5 (A. Leblanc)	○	12.5	103.4	3.5	2.0	2.75	114.4	140.2	-		2500 Level
33	Scooptram ST-5 (R. Lamothe)	○	12.75	101.2	4.9	1.5	3.2	117.7	144.25	101.5		2900 Level
34	U/G Crusher (R. Remorrine)	○	14.25	99.95	1.6	11.4	7.5	108.3	130.55	98.1		3000 Level
35	U/G Jaw Crusher (E. Labranche)	○	13.5	102.05	4.5	5.5	5.0	111.8	132.5	95.3	Wears plugs and muffs	1000 Level
36	U/G Jaw Crusher (Morrice)	○	14.0	101.8	3.3	1.0	2.15	106.0	130.75	-		2700 Level
	Mean		13.72	109.11	12.62	13.68	13.10	115.82	134.25	105.07		
	Std. Dev.		0.81	8.97	7.17	7.19	6.38	9.28	7.35	8.11		

Note: ○ Satisfactory; ◒ Good; ● Very Good

Undetermined numbers (-No.) are not in Mean value.

Attenuation tests of different models of ear muffs - OSHA mode

No	Equipment	Comfort	L_{OSHA} (dBA)	L_{OSHA} (dBA)	Attenuation (dBA)			L_{OSHA} (dBA)		L_{ISO} (dBA)				Comments	Location
					L.S.	R.S.	B.S.	Max	Peak	L_{eq} (60s)	Slow	Fast	Peak		
							EAR MUFF - MARK IV								
1	Jack Leg Drill (L. Breault)	◒	13.5	115.3	15.8	4.8	10.3	120.4	139.0	115.0	116.5	116.2	131.0		2700 level
2	Stoper Dr. Rock Bltg. (G. Trottier)	◒	14.0	111.8	21.4	16.5	19.0	117.8	>142.1	113.4	115.2	115.5	132.3	Wide brim helmet (old style)	2600 level
3	Stoper Dr. Rock Bltg. (R. Auger)	◒	13.5	112.9	16.5	15.1	15.8	121.4	143.4	118.8	117.7	117.7	133.9		2700 level
4	Jumbo Drill (Elec. Hydr.) (G. Yarkie)	◒	14.0	107.2	>24.0	17.1	>20.6	110.8	125.0	109.2	107.5	108.3	121.4		2700 level
5	Long Tom Drill (2 boom) (R. Petreault)	◒	13.5	117.9	28.7	>36.2	>32.5	126.3	>148.0	121.5	122.1	121.6	137.5		2300 level
6	Long Tom Drill (2 boom) (B. Seguin)	○	14.5	>115.0	11.3	>19.9	>16.6	-	-	122.5	121.5	122.7	136.6		2300 level
7	Diamond Drill (D. Hankinson)	○	13.75	99.2	12.3	3.0	7.7	104.7	<122.1	97.4	100.1	99.8	111.9	Muff pads in bad shape	2625 level
8	Conveyorman (G. Brunnella)	◒	13.50	88.2	>7.1	>9.3	>8.2	97.9	<120.0	88.9	87.2	87.8	105.3	Wide brim helmet (old style)	3100 level
	Mean		13.78	107.50	18.00	11.30	13.20	114.19	135.80	110.84	110.98	111.20	126.24		
	Std. Dev.		0.36	10.47	6.13	6.82	5.11	10.14	9.61	11.96	12.09	12.02	12.07		
							EAR MUFF - PELTOR (H7)								
1	Long Tom Drill (P. Lafleur)	●	13.5	117.9	13.6	14.3	14.0	120.2	139.8	117.9	117.4	117.5	137.5	Mufts worn with band at nape of neck - no head strap	2700 level
2	Long Tom Drill (2 boom) (M. Pelletier)	◒	14.0	114.3	24.6	21.0	22.8	119.1	138.7	115.7	117.4	116.4	132.0		2500 level
							EAR MUFF - BILSOM								
1	ETH - In the Hole Drill (B. Leadbeater)	○	14.0	102.4	13.5	14.7	14.1	107.7	128.4	100.3	100.0	100.0	114.2	Uses plugs only - borrowed hat and muffs	

Note: ○ Satisfactory; ◒ Good; ● Very Good.

Undetermined numbers (>No. and <No.) are not in Mean value.

Attenuation tests of different models of ear muffs - ISO mode

No.	Equipment	Comfort		L_{ISO} (dBA)	Attenuation (dB) L.S.	R.S.	T.S.	L_{ISO} (dBA) Max	Peak	L_{OSHA} (85) (dBA)	Comments	Location
						EAR MUFF - MARK IV						
1	JackLeg Drill (L. Breault)	◒	13.5	117.8	18.5	5.8	12.15	127.1	146.8	112.1		2700 level
2	Stoper Dr. Rock Bltg. (R. Auger)	◒	13.5	16.05	15.9	20.2	18.0	122.9	140.5	115.0		2700 level
3	Stoper Dr. Rock Bltg. (R. Seguin)	○	14.5	117.1	21.4	26.6	24.0	123.9	140.25	115.0		2325 level
4	Stoper Dr. Rock Bltg. (G. Trottier)	◒	14.0	109.9	22.0	11.9	16.95	121.1	141.25	-	Wide brim helmet (old style)	2600 level
5	Jumbo Drill (G. Yarkie)	◒	14.0	108.25	13.2	21.8	17.5	112.8	127.0	107.4		2700 level
6	Long Tom Drill (R. Seguin)	○	14.5	121.0	23.4	26.9	25.15	122.9	140.5	115.0		2325 level
7	Long Tom Drill (La Pensee)	◒	14.5	121.0	19.6	15.6	17.6	123.9	140.25	115.0		2325 level
8	Long Tom Drill (R. Perrault)	◒	13.5	119.85	21.5	19.7	20.6	123.1	143.25	-		2300 level
9	Diamond Drill (D. Hookinson)	○	13.75	107.5	5.1	19.0	12.05	99.85	123.0	95.6	Muff pads in bad shape	2625 level
10	Conveyer Man (G. Brunelle)	◒	13.5	87.7	9.0	6.4	7.7	95.35	120.8	92.7	Wide brim helmet (old style)	3100 level
	Mean		13.93	112.65	17.84	18.56	18.22	119.95	140.23	101.95		
	Std. Dev.		0.44	10.14	5.76	7.22	4.54	8.48	5.81	9.28		
						EAR MUFF - PELTOR (H7)						
1	Long Tom Drill (M. Pelltier)	◒	14.0	115.2	24.8	23.1	23.95	120.4	139.5	112.8		2500 level
2	Long Tom Drill (P. Lafleur)	●	13.5	120.1	20.1	26.0	23.05	121.55	141.05	115.0	Muffs worn with band at nape of neck - no head strap	2700 level
						EAR MUFF - BILSOM						
1	Hole Drill ITH (R. Leadbeater)	◒	14.0	102.3	6.0	12.4	9.2	107.5	127.45	101.0	Uses plugs only - borrowed hat and muffs	2900 level

Note: ○ Satisfactory; ◒ Good; ● Very Good.

Undetermined numbers (No. and -No.) are not in Mean value.